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Leveraging Advances in Mobile Broadband Technology to Improve Environmental Sustainability

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ABSTRACT

Advances in mobile access broadband technology have a high potential to improve environmental sustainability both directly by enabling novel network deployment concepts and indirectly by changing the way people live and work. In this paper, improvements of the network topology enabled by broadband access are investigated. It is shown that a joint deployment of macro- and publicly accessible residential picocells can reduce the total energy consumption by up to 70% in urban areas. In addition the high potential of indirect effects of improving telecommunication networks, such as enabling teleworking and replacing business travel through video conferencing, is demonstrated and compared with the direct effects.

INTRODUCTION

Improving the livelihoods of citizens around the world through sustainable development represents one of the greatest challenges facing humanity today. The necessity to manage the resources of the planet in a way that allows the long-term needs of a sustainable society to be met, while respecting the finite resources of the planet's ecosystem and achieving poverty eradication, is a challenging, but achievable, task. Broadband is unique in that it has the potential to address many sustainability challenges, while simultaneously increasing socio-economic development and quality of life. Broadband facilitates transformative change in a wide range of key sectors from power, transportation, buildings, education, health and agriculture. The impact of broadband on the Millennium Development Goals (MDGs) is now widely acknowledged. We believe broadband is a fundamental technology to achieve sustainable development that should also be recognized in future Sustainable Development Goals (SDGs).

Research Hypothesis

In recent years, the increasing cost of energy, coupled with the current international focus on climate change issues has resulted in many efforts in reducing the use of energy. Studies have shown that telecommunications can be large consumers of energy, with NTT accounting for 0.7% of Japan's total energy consumption in 2001, and Telecom Italia using 1% of Italy's total energy consumption in 2006. In Australia, it is estimated that ICT use in business accounts for 1.4% of total national emissions, with the network operator Telstra alone accounting for 0.2%. Therefore, the telecommunications industry has participated in discussions of its role in reducing its impact in this field.

While energy efficiency of networks has been important in the past, it is clear that it is becoming even more significant in coming years. One class of network systems that has been widely deployed worldwide is wireless cellular networks. Cellular networks typically require a large number, up to tens of thousands, of base stations to provide nationwide coverage. Since each base station can require – depending on the configuration, load of the cell, and age of the equipment – up to 2.7kW , the energy consumption for a nationwide coverage is in the order of several hundred MW. Cellular networks are therefore systems where the benefits of higher energy efficiency can be considerable. The advancements in broadband technologies and deployments have been rapid in the past 10 years, with high data rate data connections becoming cheap and easily available in many developed countries. The indications are that the continued expansion of broadband connections will continue at a rapid pace in the future. There is a substantial opportunity to leverage the wide availability of high speed data connections to reduce both the telecommunications industry's direct impact on the environment, as well as changing the way the public behaves to offer benefits to the environment indirectly.

RESEARCH OBJECTIVE

In this paper direct and indirect ways of how advances in broadband technology can help to improve environmental sustainability are explored. The direct benefits of improving cellular networks by using broadband technology are

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investigated. The efficiency of current macrocellular networks in delivering high data rate services, and how moving towards small cells can help to improve efficiency, is explored. Then the concept of joint macro- and picocell coverage presented, and results showing the potential benefits based on current technologies are discussed. Possible improvements of future technologies on the energy efficiency of base stations are presented, and results of the joint coverage scenario with these improvements. Two examples, the impact of enabling teleworking, and replacing business travel by video conferencing are examined and their potential benefit is quantified.

IMPROVING ENERGY EFFICIENCY OF CELLULAR NETWORKS USING BROADBAND TECHNOLOGY

Advances in broadband technology enable new approaches to deploying cellular networks which can potentially bring significant improvements in terms of capacity and energy efficiency compared to traditional macrocellular deployments. In this section the potential benefits of a joint macroand residential picocell deployment are explored based on today's technology.

Efficiency of today's Macrocelular technology and Challenges

Macrocellular network deployments have in the past been effective in providing coverage for voice and low-speed data traffic. However, one of the most obvious trends in wireless communications is the move towards higher data rates. Macrocells are characteristically good at providing area coverage, but are not as effective in providing high data rates per area due to their typically large coverage. While there have been many different approaches made to improve the spectral efficiency of macrocells and provide the required capacity in the future, macrocells are still generally limited due to the shared bandwidth for a large coverage area. One of the recent developments towards the direction of smaller cells is the introduction of femtocells. Femtocells are low-power, low-cost, user-deployed base stations, designed for use in residential or enterprise environments. They also typically employ the user's DSL or cable broadband connection as backhaul connection to the mobile operator's core network. Femtocells are expected to initially be deployed with access restricted to private users only. However, when public access to femtocells is implemented, there is a huge potential of exploiting widespread femtocell deployments to significantly reduce the energy consumption of cellular networks by using the deployed femtocells to supplement the capacity of the macrocellular network. This concept requires femtocells to have a larger range of several tens of meters, such that its coverage can extend to the outside of the home or office it is deployed in. In the rest of this paper, publicly accessible femtocells with such enlarged ranges are referred to as residential picocells.

Efficiency of Joint Macro- and Residential Piocell Deployments with current Technology

Residential picocells are deployed in conjunction with a wide area cellular network for area coverage in an urban environment as illustrated in Figure 1.

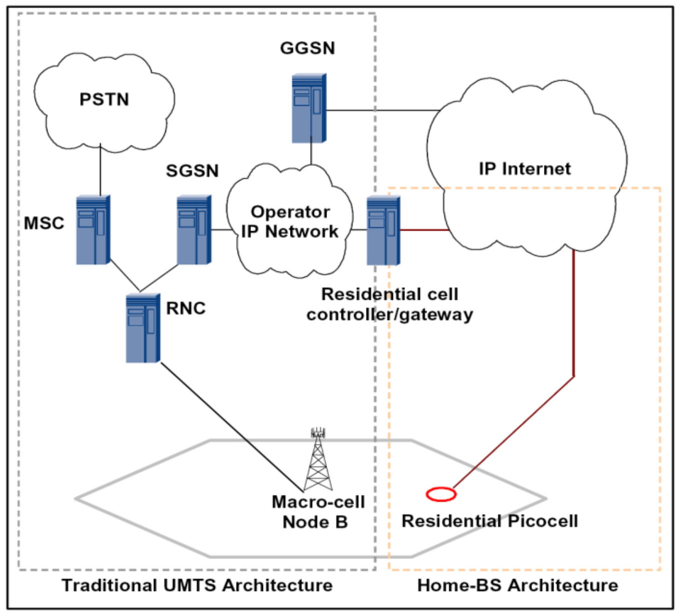

Figure 1 Overview of macrocellular underlay network with residential picocell overlay deployment

The financial impact of such a mixed macro- and picocell topology was studied and it was shown, that such a mixed deployment can significantly reduce the total network costs. This paper focuses more on the network energy consumption, the related costs, and CO2 emissions for such networks based on current and future technologies.

IMPACT OF FUTURE TECHNOLOGIES ON EFFICIENCY

While the results indicate that a mixed macro- and picocell topology can improve the energy efficiency in urban areas

based on today's technology, future improvements of these systems will have a high impact on the results. In this section, different possible improvements for both macroand picocells are discussed, which can further improve the efficiency, and their impact on the total energy consumption is estimated.

Macrocell Improvements

Macrocellular base stations are one of the biggest contributors to the overall energy consumption of a wireless network. Approximately 60% to 70% of the energy required by a base station is consumed by the power amplifier (PA) units. Therefore, any enhancement of the power amplifiers will have a direct and significant impact on the power consumption of the entire network and its associated CO2 emission. Further improvements can be achieved by introducing enhanced architectures, which won't require today's expensive, long and therefore lossy cable assemblies. So significant efficiency improvements can be achieved in terms of two aspects: the power amplifiertechnology itself and the overall base station architecture.

Depending on the state of the technology, the age of the equipment, and the standard (GSM, UMTS, CDMA etc.), the total efficiency of the currently deployed amplifiers range anywhere from 5% to 20% (total efficiency here in the sense of the total efficiency from AC power input to generated RF output power). The efficiency on the component level (in the sense of the amplifier transistors of the final amplifier stage) of today's amplifiers for CDMA and UMTS systems is in the order of approximately 30% to 40%, depending on technology and implementation. But the performance of the required semiconductor components and of the amplifier architecture itself is still a matter of research. It can be assumed that the achievable component efficiency of such devices will be in the order of 70%. If such amplifiers would replace the current power amplifier installations, this would reduce the power consumption of the currently installed power amplifier infrastructure by roughly 50% while maintaining the same RF-output power capability. Another major drawback of the currently deployed technology is the fact that the amplifiers are designed to perform best at maximum output power conditions. This is necessary to maintain the required signal quality at maximum output power, but this condition is met only at a fraction of the time (<10%) during operation. For the rest of the time, especially at night time when traffic is minimal or zero, this results in a tremendous waste of energy, since the bias of the power amplifier is still maintained for maximum power conditions. To improve this, it would require either a flexible biasing of the PA or the parallelisation of several smaller power amplifiers, which can be individually turned on and off. he design of such flexible power amplifier architectures, which would allow a better adaptation of the amplifier to the required output power, is also matter of current research effort.

Approximately 50% of the signal power, which is available at the power amplifier output, is lost in cables, feed-networks, filters and connectors until it reaches the antenna element itself. Therefore current developments aim to move the RF-power amplifier closer to the antenna. The connection between the cabinet and such a tower top amplifier is usually done by an optical cable or a low-power RF-cable. It would be even more beneficial to place a smaller, more flexible power amplifier directly behind each antenna element, to avoid any cables or feed networks between the amplifier and the antenna.

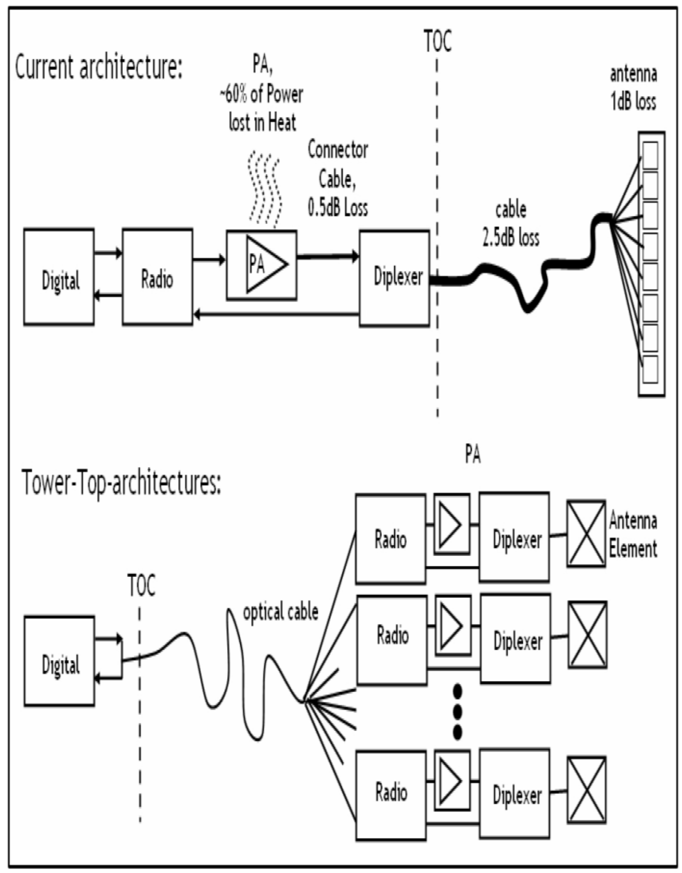

Figure 2 Macrocell base station architectures

Based upon the assumption that it will be feasible for future power amplifiers to push the component efficiency to 70% and by cutting the losses in the current systems in half, it can be estimated that the power consumption of the power amplifiers of base stations can be reduced by between 50% and 75%.

This would result in an overall improvement of 33% to 50% of the entire base station power consumption. For the analysis in this paper a conservative estimation of an improvement of 33% is assumed.

INDIRECT EFFECTS OF IMPROVING BROADBAND NETWORKS

In addition to the direct improvements in efficiency of networks that can be achieved as described above, advances in broadband technology also have a high potential to improve the environmental sustainability indirectly by changing the way people live and work.

Telenetworking

One of the main potential benefits of telecommunications is that it enables the concept of teleworking. Teleworking can be defined as an arrangement where the employees are given the flexibility in their working location, such that the employee's daily commute to a traditional place of work is replaced for a significant portion of days by telecommunication links. A precise definition of teleworking is difficult to give, because there are jobs that by their nature require the employee to spend significant amounts of time outside of a fixed place of work, such as field technicians and salespeople. But generally, the assumption used here is that teleworking creates a new way of working remotely for the employee.
The economic benefits of teleworking are numerous. For example, there are obvious benefits in lower costs for employers in real estate and facilities, and in lower commuting costs for the employees. Teleworkers also tend to be healthier, and take less sick leave since employees are exposed less to factors such as pollution and stress during the daily commute, and airborne germs that can spread amongst colleagues in the office. If planned properly, teleworkers can also work more efficiently (up to 45% improvement in efficiency due to spending less time in commute, and being fresher when performing the work, and at the same time, also have more leisure time.
There are also, however, disadvantages to teleworking, such as the initial costs of providing the infrastructure and training for migrating employees to a teleworking arrangement. It may also result in difficulty for managers to perform close supervision of employees. Close teamwork and communication would also not be as good as face-to-face interaction, although the advances of technologies such as high quality video conferencing and collaborative software can reduce the impact of this.

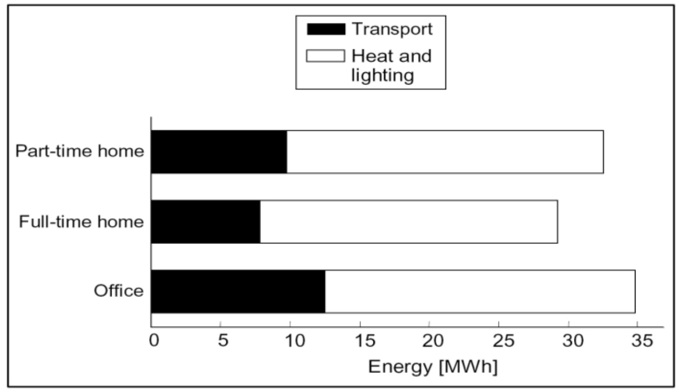

Figure 3 Annual energy profile for three different work arrangements Replacing Air Travel by Video Conferencing

Advances in broadband technology can be used to significantly improve the environmental sustainability is the possibility to reduce air travel for business meetings. This can be achieved by using high-quality video conferencing as a replacement for a business trip, which results not only in a significant reduction of CO_2 emissions due to the reduction in the number of required flights, but also reduces the travel costs and work time required (i.e. salary costs) for such trips.
Video Conferencing act as a replacement for travel has a high potential to reduce the impact of air travel on the environment, and can result in significant cost reductions for corporations.

COMPARISON OF DIRECT AND INDIRECT BENEFITS

The direct benefits resulting from improvements of the telecommunication networks can result in substantial reductions in energy consumption, CO_2 emission, and cost. However, it is also shown that the potential indirect benefits resulting from changes in the way people live and work, have a far greater potential and exceed the direct improvements by orders of magnitude. Teleworking from home and replacing business travel with video conferencing have an enormous potential for reducing the use of natural resources and the emission of greenhouse gases if the user experience can be improved. This can for example be achieved by future

advances in broadband technology to provide the required high data rates, by improvements in video compression, and by new user friendly, intuitively operable, and reliable applications. In the future a two-sided approach will be required: Leveraging advances in broadband technology to directly improve the efficiency of telecommunication networks, and on the other side to promote changes in the way how these networks are used. This way, advances in broadband technology can play a major role in reducing the emission of greenhouse gases and can significantly contribute to improving environmental sustainability.

An encouraging fact is that these environmental benefits do not come at high costs, but can in addition result in a significant cost reduction for network operators, corporations and individuals. These financial incentives will be the main driver to change towards a more sustainable behaviour.

CONCLUSIONS

In this paper, direct and indirect ways of how advances in broadband technology can help to improve environmental sustainability have been explored. The effects of a joint macro- and picocell deployment on the network energy efficiency, enabled by widely available broadband access, have been investigated. It was shown that a joint deployment of macrocells for area coverage and publicly accessible user-deployed residential picocells can reduce the total network energy consumption by up to 60% in urban areas for high data rate user demand based on today's technology. In addition, the impact of future technologies on the energy consumption was investigated, and it was shown that benefits of a joint macro- and picocell deployment will increase further to a maximum of up to 70% of the energy consumption as both technologies mature and the demand for high data rates increases.

In addition the high potential of indirect benefits of improving telecommunication networks, such as enabling teleworking and replacing business travel through video conferencing, was demonstrated and compared with the direct benefits.

It was shown that the indirect benefits to the environment resulting from changes in the way people live and work are orders of magnitude higher that what can be achieved directly by improving telecommunications networks alone. The direct and indirect approaches discussed also result in a significant cost reduction for network operators, corporations and individuals, which will be the main driver to change towards a more sustainable behaviour in the future.

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